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ABSTRACT

This instructor's guide on solar heating and cooling is part of a series of individualized instructional materials. The guide is provided to help the instructor make certain that each student gets the most benefit possible from both the student's manual and what he/she does on the job. Notes for the instructor contain suggestions on how the student should use the student's manual. Other contents of the guide include answers to exercise questions and assignment test questions, one set of assignment tests, a progress record, and work sheets that the instructor can use to relate instruction to job experience for the student. Topics covered are occupational outlook safety, planning for solar conditioning, heating and cooling systems, controls and plumbing, solar equipment, and installation and maintenance of solar energy systems. (YLB)

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Introduction to Solar Heating and Cooling Systems

Instructor's Guide

D.O.T. 637.281 and .381

By
L. A. Grimes, Jr.

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Foreword

This publication is one of the Extension Instruction and Materials Center series of individualized instructional materials. Each student who uses this material can work at his or her own pace, learning those things that best fit specific needs. The design of the material makes it possible to relate work experience on the job with information studied at school.

Although the material is self-paced, it should be used under the supervision of a coordinator or instructor. Two basic publications are offered—a student's manual and an instructor's guide.

The *student's manual* is for the person in training. It is self-contained. Each assignment has all the information needed, a list of objectives that should be met, and exercise questions that can help in meeting those objectives.

The *instructor's guide* has additional information that may help the instructor help the student. There are suggestions on how the student should use the student's manual and how the instructor can coordinate work experience and learning at school. The instructor's guide also contains (1) answers to both exercise questions and assignment test questions, (2) one set of assignment tests, and (3) a work sheet that the instructor can conveniently use to match related instruction to job experience for the student.

Although both publications are copyrighted, an instructor should feel free to reproduce copies of the assignment tests and work sheet. To make that possible, we have placed the tests and work sheet in a separate section of the instructor's guide, where they are readily accessible for copying. If the instructor prefers, copies of these same sheets for individual students can be ordered separately from Extension Instruction and Materials Center, P. O. Box 7218, The University of Texas at Austin, Austin, Texas 78712.

Jack E. Robertson, Ph.D.
Director, Extension Instruction
and Materials Center

Preface to the Student's Manual

Solar heating and cooling is one of the newest forms of energy systems and has gained attention with the realization that conventional energy sources may soon be exhausted. A great deal of time and effort has already been spent on developing various methods to tap this practically limitless source of energy.

This manual has been written for the primary purpose of introducing the student to the methods being employed to use this resource. Solar energy has been used for heating water for nearly sixty years, but solar space heating and cooling is only now beginning to be considered a viable alternative. The future for solar heating and cooling looks bright, and the sun could well be the primary source of energy in another twenty or thirty years.

L. A. Grimes, Jr.
Curriculum Specialist

Notes for the Instructor

The instructor's guide is provided to help the instructor make certain that each student gets the most benefit from the student's manual and work on the job. To do so, this guide includes the following:

1. notes for the instructor;
2. answers to assignment exercises;
3. answers to assignment tests;
4. assignment tests, in the form in which they will be used by the student; and
5. work sheet for planning and recording work experiences and related assignments from the student's manual.

These notes and all answers to exercise and test questions should be kept by the instructor. The actual assignment tests and work sheet may be removed to be used or reproduced. For convenience, this guide is punched for notebook use.

Occupational Requirements and Student Background

The determination of content for the student's manual was based on studies, observation, and interviews with solar industrial firms and on various current textbooks in the solar heating and cooling field.

People employed in solar heating and cooling work in the general field of building trades. They are responsible for the planning and installation of various types of solar heating and cooling systems. They are responsible for installing controllers, thermostats, and sun tracking controls. They may also install exchangers, absorbers, and dampers. They will advise users on installing insulation and see that the structure is equipped with filters, collectors, and shading devices.

Solar heating and cooling personnel work closely with carpenters, plumbers, sheet metal workers, bricklayers, roofers, and other similar workers. They must be able to use complicated formulas to figure heat loads and radiation effects on various materials. They must be able to read blueprints and have a safety awareness of the elements and equipment with which they are working. Solar energy workers must have good mechanical aptitude and manual dexterity. They must be strong enough to lift objects of moderate weight, such as heating panels.

Assignment Design and Teaching Principles

The student's manual presents related technical information to (1) groups of trade and industrial students with various vocational objectives and (2) homogeneous groups in which the learning levels of individual students vary considerably. The student's manual is not intended to be used as a correspondence course. Instead, it must be used by students under the direct supervision of an instructor.

Each assignment in the student's manual is designed to use as many fundamental teaching principles as possible. For that reason, each assignment is broken down into four parts—objectives, technical information, exercise, and test.

Objectives. The first teaching principle is that the student should be informed at the outset about what should be learned from an assignment. The statement of objectives for an assignment is based on this principle. These are performance objectives that can be tested when the assignment is completed.

Technical Information. The second teaching principle is that technical information should be presented in a complete but concise form. All the information needed to complete the assignment exercise and meet the objectives is found in the assignment itself. This information has been organized to help the student learn more easily—either step-by-step, moving from simple to complex, or by logical topics and subtopics.

Exercise. The third teaching principle is that technical information is better learned if it can be applied as soon as possible after it is presented. This theory is put in practice by using an exercise for each assignment. The exercise questions are phrased to emphasize key points and to aid in evaluating the technical information. The instructor should emphasize to students that the objectives and the technical information should be read before they attempt to answer the questions in the exercise. An exercise is not an open-book test, and this approach to the exercises should be discouraged. The answers may be useful in helping a student who is having difficulty with an assignment test.

Test. The fourth major teaching principle is that the effectiveness of an assignment should be evaluated. This is made possible by brief assignment tests provided in this guide. A test should be given when an assignment is completed. Each assignment test is based on the objectives stated for that assignment.

The answers to both assignment exercises and assignment tests have been made as brief as possible to make it easier for the instructor to check the student's classroom work quickly and accurately. All answers should be retained by the instructor for obvious reasons.

Tests and Work Sheet

The last section of this guide contains the tests and work sheet, which can be removed for reproduction or other uses. The tests and work sheet may be reproduced without the publisher's permission. Sets of the material in the last section can also be ordered separately from Extension Instruction and Materials Center.

Answers to Exercises

Exercise A-1

Using This Manual

1. related technical instructions, procedures, and illustrations
2. the combination of backup training in theory and the actual work on the job
3. (1) objectives
   (2) information
   (3) exercise
   (4) test
4. before reading the information part of the assignment
5. Read the assignment information and study all illustrations.
6. tools and materials, as well as certain procedures and operations
7. when answering exercise questions or when certain tasks on the job make it necessary
8. to help the student meet the assignment objectives
9. in the form of a complete sentence
10. Correct any mistakes, and place the papers in their notebooks.
11. when the exercise questions have been answered correctly
12. make the student think
13. as soon as the assignment has been completed, or several individual tests may be combined and given together as a weekly or six-weeks' test
14. fill-in-the-blank and multiple-choice questions

Exercise A-2

The Future of Solar Environment Careers

1. to see how they affect individuals
2. to make the best use of solar energy
3. both active and passive systems
4. controls and backup systems
5. Clean the system and maintain it.
6. in the southern and western parts of the United States
7. to figure heat loads and radiation effects on various materials
8. because it is a new field and few people are skilled and knowledgeable in it
9. the initial cost

Exercise A-3

Safety Using Solar Energy

1. in heat transfer chemicals, heat pump and air conditioner fluids, materials for washing collector fields, and mechanical device lubricants
2. accidental pollution
3. Pump failure or transfer pipe blockages may elevate temperatures and open relief valves.
4. holding tanks
5. antifreeze, ethylene glycol, hydrocarbon, or high boiling oil
6. Fluid in the system might be discharged into a septic tank or sewer system.
7. ear protectors
8. when there is flying sawdust, metal, or other particles that might cause eye injury
9. exposure to hot pipes or collectors

Exercise B-1

Heat Stress on the Individual

1. in relation to the temperature of the air
2. air temperature, air movement, humidity, and radiant temperatures
3. It gives a cooling effect.
4. drying out of the skin or noise problems
5. It gives a "sticky" feeling or a feeling of closeness. It may also make breathing more difficult.
6. discomfort to the throat and nasal passages
7. when we are exposed to the sun
8. by keeping the sunlight from penetrating an interior or by letting it enter at an angle to receive as little direct radiation as possible

Exercise B-2

Financial Considerations

1. (1) the special design of the structure to house the system
   (2) the materials and equipment needed for collectors and storage units
2. a backup system
3. from the lifetime use of them
4. the low operational costs
5. antifreezing elements
6. up to $2,000
7. loan programs
8. a franchise tax exemption
9. 55 percent of the initial cost up to a maximum credit of $3,000
10. veterans

Exercise B-3

Structural Design

1. height and type of building
2. direction of prevailing winds, average temperatures, and average rainfalls, as well as average number of cloudless days
3. additional braces and special flashing
4. air movement throughout the structure
5. glass fiber, rock wool, plastic foams, and reflective foil laminates
6. Add more insulation.
7. insulated foam
8. thermal
9. by wrapping them with insulation materials and adding some type of antifreeze

Exercise C-1

Active Systems

1. some mechanical means
2. in the furnace plenum or return air duct
3. a circulating pump
4. water, water and antifreeze, or steam
5. chilled water
6. by natural convection and radiation similar to the method of steam radiators
7. in the floors or ceilings
8. no freezing problems, no water leaks in the system, lower installation cost, and no danger of pressure buildup in the pipes
9. through a duct housing to an air-to-water heat exchanger

Exercise C-2

Passive Systems

1. fans
2. to capture the heat, so that air passing over them will carry heat into the building, and to store heat for use at night
3. to absorb the sun's rays
4. pulls it through the openings in the bottom of the walls
5. The air vents are closed by dampers.
6. about 4 inches
7. the maximum benefits of sunlight entering into the building

Exercise C-3

Cooling Systems

1. wood or concrete
2. steel mesh
3. those 1 to 1½ inches in diameter
4. a sensor
5. water
6. They are covered with insulating foam panels.
7. water heated to about 240°F that is pumped through a collector flow loop to a heat exchanger
8. a gas or electrical hot water heater
9. a heat pump driven by solar energy
10. liquid system solar collectors, heat pumps, centrifugal pumps, and thermostatic controls

Exercise C-4

Hot Water Conditioning

1. as early as 1923
2. stone
3. coils in the storage tank
4. a thermostat
5. a thermosiphoning system
6. so that siphoning can take place
7. a black plastic collector
8. the type of collector used

Exercise D-1

Controls

1. if the water heater is conventional and has a mixing valve on the output side
2. a sensor
3. to keep water as high as 160°F from being introduced into the hot water tap
4. to measure temperatures of the rock bin or storage tank, the environment, the heated space, and the air or water coming from the solar panels
5. to turn the pump off or on when the temperature reaches certain points
6. to keep the pump from being turned on every time there is a brief fluctuation in temperature, which saves wear on the pump and pump motor
7. from about 6 P.M. until 8 A.M.
8. It keeps a more even level of temperature.
9. photovoltaic sun sensors
10. They turn on a motor drive system to track the sun.

Exercise D-2

Pumps, Valves, and Pipes

1. affect the flow of the liquids and require that a larger pump or motor with more horsepower be used
2. cavitation
3. bronze or stainless steel
4. when glycol solutions are used in the circulatory system
5. below other points in the system
6. collectors, pumps, heat exchangers, and storage tanks
7. when the system contains high-temperature solvents such as silicone working fluids or glycol solutions
8. mixing valves
9. when each circuit of the system is connected in parallel
10. They should be routed outside the structure. Toxic materials should go into a holding tank.
11. to stop any reverse flow in the pipes
12. low pressure from a gravity flow, rather than the pump
13. copper or steel
14. size of the system, type of pump, and number of turns in the pipe

Exercise E-1

Filters, Collectors, and Shading Devices

1. strainers
2. to reduce or eliminate dust and other airborne particles that can cause discomfort and activate allergies, and to help keep the rock bin clean
3. (1) a dark surface exposed to the sun to absorb energy
   (2) transparent glass or plastic to admit and contain short wavelengths of the sun's energy
4. (1) using the overhang of the roof to direct sun through the windows and walls or into bottled water
   (2) using the roof
5. a steel, aluminum, or plastic plate or sheet painted a dark color; tubes to carry the fluid; a sheet of glass or plastic; insulation; an inlet; and an outlet
6. to keep the heat from escaping
7. geographic location, design of the collector panels, number of occupants, and how much heated water the structure's appliances will demand

8. by insulated panels that are easily fastened or slid above the collectors when needed
9. to reflect the heat away from the collectors

Exercise E-2

Heat Exchangers, Absorbers, and Dampers

1. It is usually a coil of copper tubing that transfers heat from solar-heated water in the exchanger to the surrounding water in the storage container.
2. A smaller temperature difference is required to heat the water to a specific temperature.
3. (1) shell and tube
   (2) shell and double tube
   (3) double wall
4. to alert the user if there are tube failures
5. the tubing
6. a steel absorber panel coated with a highly absorbent black ceramic coating
7. because of these metals' ability to withstand elevated temperatures and because they lose less heat than other metals
8. aluminum
9. welded or soldered
10. dampers
11. early breakdowns, system leakage, or coil freeze-up
12. Feed scented air into the system.

Exercise F-1

Installation and Maintenance of Solar Energy Systems

1. all building codes
2. 6 inches
3. They should have flashing and caulking applied.
4. before any walls or other areas are closed
5. termite shields
6. They should be well insulated.
7. the weight of the parts, liquid loads, and snow loads in the winter
8. those of poor quality or those with open or loose knots
9. soldered and wrapped at the joints
10. relief valves
11. both liquid and metal expansion
12. to see that no fungi have attacked the rock
13. warning lights
14. because at times the system must be drained and cleaned, or an antifreeze solution changed or added
15. They should be kept away from pipes or other areas where fumes or leakages could cause contamination.
16. Install proper bracing until the new structural additions are made.
17. Inspect it or have an expert check it.
18. a maintenance schedule or checkoff list with any emergency procedures to be followed in case of a serious problem

Answers to Assignment Tests

Test A-1
Using This Manual
1. Student's manuals
2. objectives
3. exercise
4. objectives
5. c. multiple-choice

Test A-2
The Future of Solar Environment Careers
1. passive
2. clean
3. initial cost
4. southern / western

Test A-3
Safety Using Solar Energy
1. Accidental
2. Holding
3. ear
4. collectors

Test B-1
Heat Stress on the Individual
1. temperature
2. cooling
3. humidity
4. radiant

Test B-2
Financial Considerations
1. backup
2. operational
3. $2,000
4. loan

Test B-3
Structural Design
1. height
2. braces / flashing
3. foam
4. Thermal

Test C-1
Active Systems
1. return
2. natural
3. Hydronic
4. pump

Test C-2
Passive Systems
1. Fans
2. dark
3. Convection
4. sunlight

Test C-3
Cooling Systems
1. concrete
2. sensor
3. foam
4. 240°F
5. heat

Test C-4
Hot Water Conditioning
1. stone
2. pump
3. thermosiphoning
4. collector

Test D-1
Controls
1. sensor
2. differential
3. 160°F
4. lag
5. photovoltaic

Test D-2
Pumps, Valves, and Pipes
1. Cavitation
2. glycol
3. Gate-and-ball
4. Mixing
5. reverse
6. Copper

Test E-1
Filters, Collectors, and Shading Devices
1. Strainers
2. rock bin
3. plastic
4. collector
5. insulated

Test E-2
Heat Exchangers, Absorbers, and Dampers
1. increased
2. tube
3. aluminum
4. dampers

Test F-1
Installation and Maintenance of Solar Energy Systems
1. closed
2. insulated
3. fungi
4. lights
5. maintenance

Assignment Tests and Work Sheet

for

Introduction to Solar Heating and Cooling Systems

For Your Convenience . . .

- *Pages in this section may be reproduced without permission by any instructor for teaching purposes.*
- *Instructors who do not want to reproduce the material can purchase separate sets of just this section from Extension Instruction and Materials Center, The University of Texas at Austin, P. O. Box 7?18, Austin, Texas 78712.*
- *Each assignment test is based on a specific assignment.*
- *The work sheet is provided for use as a weekly log. On each sheet is listed the contents of the student's manual, readily available for coordinating assignments with work experience.*

TEST A-1

Using This Manual

---

1. _____ _____ _____ are designed to present related technical instructions, procedures, and illustrations to the student.

2. The assignment _____ _____ should be studied before reading the information part of the assignment.

3. All assignment _____ answers should be written in the form of a complete sentence.

4. It is assumed that the assignment _____ have been met when the exercise questions have been answered correctly.

5. Assignment test questions in this manual are either fill-in-the-blank or—
   a. true-false.
   b. matching.
   c. multiple-choice.
   d. essay.

TEST A-2

The Future of Solar Environment Careers

1. Both active and _____ systems are used for solar heating and cooling.

2. The worker must be able to _____ the system and maintain it after it has become operational.

3. One of the largest problems in solar heating and cooling up to this point has been the _____.

4. Most of the solar energy employment will be in the _____ and _____ parts of the United States.

TEST A-3

Safety Using Solar Energy

---

1. _____ pollution can occur if the necessary precautions are not taken.

2. _____ tanks should be used to catch released liquids.

3. Workers should use _____ protectors during setup and equipment checks.

4. Typical injuries when working with solar systems occur during work in which hot pipes or _____ are exposed.

TEST B-1

Heat Stress on the Individual

1. We usually define how comfortable we are in relation to the _____ of the air.

2. Air movement gives the person a _____ effect.

3. Low _____ may cause discomfort to the throat and nasal passages.

4. We receive _____ temperature when we are exposed to the sun.

TEST B-2

Financial Considerations

1. A _____ system is needed in localities where there are not enough cloudless days.

2. The low _____ costs are important when using solar energy for cooling and heating.

3. Up to _____ federal tax credit is allowed on certain types of solar equipment.

4. Some states subsidize _____ programs to increase the construction of solar energy systems.

TEST B-3

Structural Design

---

1. Some zoning ordinances determine _____ and type of building.

2. Additionai _____ and special _____ are needed when installing the solar collector on the roof of a structure.

3. Electrical outlet boxes should be insulated with _____.

4. _____ panes should be installed in windows and doors.

TEST C-1

Active Systems

1. The water-to-air heat exchanger is placed in the plenum or _____ air duct of a central forced-air furnace.

2. Convectors with no fans transfer heat by _____ convection and radiation similar to the method of steam radiators.

3. _____ radiant panels are placed in the floors or ceilings of a structure.

4. A circulating _____ is used to force hot water from a storage or holding tank to the heat exchange.

TEST C-2

Passive Systems

---

1. _____ are usually the only mechanical devices found in passive systems.

2. One passive system uses a thick concrete wall painted a _____ color to absorb the sun's rays.

3. _____ pulls the air through openings in the bottoms of walls when fans are not used.

4. When building passive systems, utilize the maximum benefits of _____ entering the building.

TEST C-3

Cooling Systems

---

1. Rock bins are usually constructed of either wood or _____.

2. A _____ is placed in a rock bin to indicate the temperature of the stones.

3. Skytherm bags give summer cooling by being covered with insulating _____ panels during the day.

4. Water is heated to about _____ to operate absorption chillers.

5. Rankine engine cooling is in practical terms a _____ pump driven by solar energy.

TEST C-4

Hot Water Conditioning

---

1. The Joule box solar water heater storage tank is lined with _____ _____.

2. A thermostat turns the _____ in a Joule system off and on automatically.

3. A _____ system does not contain a thermostat or pump.

4. The efficiency of solar water heaters depends on the type of _____ used.

TEST D-1

Controls

---

1. A _____ must be placed in the upper part of a tank that has no mixing valve.

2. A _____ thermostat turns the pump off or on when the temperature reaches certain points.

3. A mixing valve keeps water as high as _____ from being introduced into the hot water tap.

4. A hysteresis or _____ feature in a differential thermostat keeps the pump from being turned on every time there is a brief fluctuation in temperature.

5. Sun tracking controls make use of _____ sun sensors.

TEST D-2

Pumps, Valves, and Pipes

1. _____ may occur if there is not adequate net positive suction head at the pump inlet.

2. Galvanized pumps should not be used when _____ solutions are used in the circulatory system.

3. _____ valves are used to isolate collectors, pumps, heat exchangers, and storage tanks.

4. _____ valves are used to keep the water from being too hot at the tap.

5. Check valves are used to stop any _____ flow in the pipes.

6. _____ or steel pipes are normally used in solar energy systems.

TEST E-1

Filters, Collectors, and Shading Devices

---

1. _____ are sometimes used to clean out waste products when a liquid system is first placed in operation.

2. An air filter reduces or eliminates dust and other particles and helps keep the _____ _____ clean.

3. A simple flat plate collector contains a plate usually made of steel, aluminum, or _____

4. A sheet of glass or plastic over a _____ keeps the heat from escaping.

5. Collectors are usually shaded in the summer by _____ panels.

TEST E-2

Heat Exchangers, Absorbers, and Dampers

---

1. If the size of a heat exchanger is _____, a smaller temperature difference is required to heat the water to a specific temperature.

2. A dye is sometimes used in the toxic liquid to alert the water users if there are _____ failures.

3. _____ plates are hard to repair if leaks develop.

4. _____ regulate air flow in air systems.

TEST F-1

Installation and Maintenance of Solar Energy Systems

---

1. Pipes and tubing should be checked for leakage before any walls or other areas are _____.

2. If there are combustible parts in the collector, they should be well _____.

3. Rock bins should periodically be checked for _____.

4. Warning _____ should be installed to indicate any malfunctions in the system.

5. Set up a _____ schedule or checkoff list after the system is in operation.

CONTENTS OF STUDENT'S MANUAL

Section A. Introduction to Solar Heating and Cooling Systems
- A-1: Using This Manual
- A-2: The Future of Solar Environment Careers
- A-3: Safety Using Solar Energy

Section B. Planning for Solar Conditioning
- B-1: Heat Stress on the Individual
- B-2: Financial Considerations
- B-3: Structural Design

Section C. Heating and Cooling Systems
- C-1: Active Systems
- C-2: Passive Systems
- C-3: Cooling Systems
- C-4: Hot Water Conditioning

Section D. Controls and Plumbing
- D-1: Controls
- D-2: Pumps, Valves, and Pipes

Section E. Solar Equipment
- E-1: Filters, Collectors, and Shading Devices
- E-2: Heat Exchangers, Absorbers, and Dampers

Section F. Installation and Maintenance of Solar Energy Systems
- F-1: Installation and Maintenance of Solar Energy Systems

WORK SHEET

FOR COORDINATING JOBS WITH RELATED INSTRUCTION USING
INTRODUCTION TO SOLAR HEATING AND COOLING SYSTEMS

This form is for your convenience in planning and keeping records of training. Contents of the student's manual are at the left. The columns below provide space for listing job experiences for the individual student and assignment numbers and other references related to each job. Blanks are large and divided by days so the teacher and student can list other information that might be useful in a weekly log.

Student _____

Training Station _____

JOB EXPERIENCES	RELATED INSTRUCTION
Monday Work Hrs:	
Tuesday Work Hrs:	
Wednesday Work Hrs:	
Thursday Work Hrs:	
Friday Work Hrs:	